PATENT SPECIFICATION

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DRAWINGS ATTACHED

1 257 963

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(54) PROCESS AND APPARATUS FOR CASTING METAL WITH SOLIDIFICATION UNDER PRESSURE

(71) We, TOYOTA CENTRAL RESEARCH AND DEVELOPMENT LABORATORIES, INC., a Corporation duly organized under the Laws of Japan, of 2—12, Hisakata, Showa-Ku, Nagoya-Shi, Aichi-Ken, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This inventon relates generally to the process of casting metal with solidification under pressure, in which molten metal in a metal mould is pressed by a ram and solidified under high pressure to produce a casting having a desired shape. This process is distinguished from conventional die casting processes in that the latter are generally confined to metals or alloys having comparatively low melting temperatures, whereas the process to which the invention refers may be applied to metals, such as alloy steels, which have much higher melting temperatures. In normal die casting practice gases are usually released from the die through a vent provided therein, whereas in the process to which the invention refers the gases are released through a clearance around the ram by which the pressure is applied to the cast metal while it is setting. The process to which the invention relates has been variously described as liquid metal forging, squeeze casting and extrusion casting but it will be referred to herein as the casting of metal with solidification under pressure. In the method and apparatus according to the invention a sealing member is utilized, attached to the ram, which initially allows gas to pass and is then deformed by heat and pressure to prevent leakage of the molten metal into the clearance space between the mould and the ram, so that pressure from the ram to the molten metal is applied more effectively and the life of the mould and the ram are prolonged.

Throughout the specification and the claims the term "molten metal" is defined to include molten and partially molten metal which is to be cast and pressed to a desired shape.

In conventional process of casting with solidification under pressure, molten metal is poured into a metal mould, and a ram of a size having a predetermined clearance in the wall of the pressure portion of the mould is inserted therein. High hydraulic pressure is then applied to the molten metal by the ram until solidification of the metal is completed. The resultant product evidences fine grain and compact internal structure. In order to retain the ram pressure (generally from 500 to 2000 kg/cm^2) effectively until the solidification of the molten metal is completed, the clearance between the ram and the wall surface of the pressure portion of the metal mould is made as small as possible (from 0.01 to 0.05 mm.), and the molten metal, which is squeezed into the ram clearance space when pressure is applied, is quickly cooled and is made to work as a packing, hereinafter termed "self-packing". However, there is a strong tendency for the packing to freeze the ram and mould together and when the ram clearance is too small, the wall surface of the mould and the ram come in contact with each other, causing galling, and damage increases until the mould is broken by the tremendous friction between the self-packing, or flash, and the mould. Another disadvantage is that the pressure-effect of the ram is reduced, and it becomes impossible to exert sufficient pressure on the central portion of the molten metal because the surrounding portion of the molten metal is quickly solidified, producing a resistance to pressure which the ram cannot overcome.

When the molten metal to be cast is one of the metals belonging to the group of aluminium, or copper, the wear and damage to the mould is relatively small, but when the molten metal is one of the metals of the iron group, the hardness of the self-packing

[Price [illegible]

is remarkably high as it becomes iron oxide, or the like, and, therefore, the mould and the ram are greatly damaged when pressure is applied, and often to an extent that they are usable only once and cannot be further employed. It has been suggested that a mould reinforcement be used in the form of an anti-abrasive alloy such as a molybdenum alloy placed at the portion of the mould most subject to abrasion, but this has been found to be almost useless. Especially, in casting molten metals of the iron group, the above mentioned disadvantages and drawbacks have led to poor results and little progress in the art of casting with solidification under pressure.

In the present invention, the pressure is applied by the ram, as in the conventional method, but the ram, instead of directly pressing against the molten metal, is provided with a sealing member in the form of a metal plate interposed between the molten metal and the pressure applying surface of the ram, and when pressure is applied by the ram to the molten metal the metal plate is plastically deformed by the resultant high temperature and high pressure. The rim of the sealing plate is thereby deformed to fit closely to the wall surface of the pressure portion of the mould, and acts as a seal to prevent entrance of the molten metal to the clearance space between the mould and the ram. As a result, no flash is formed, abrasion and flash damage are prevented, and the pressure of the ram is more effectively applied to the molten metal. The rim of the sealing plate has its hardness lowered by the high temperature, and moves smoothly in contact with the wall surface of the metal mould during the entire time the ram is being lowered.

From the above brief description it will be apparent that a primary object of the invention is to provide an improvement in the technique of casting with solidification under pressure which will overcome the defects and disadvantages of the previously outlined conventional method of liquid metal forging.

In one aspect the invention consists of a process of casting metal with solidification under pressure which includes the steps of pouring molten metal into a mould, applying high pressure to said molten metal by means of a ram which is inserted in said mould with an initial clearance therearound, and compressing said molten metal while it solidifies, comprising the step of inserting between a pressure-applying surface of the said ram and the said molten metal a sealing member made of a thin metal plate, the said sealing member having a clearance between its peripheral edge and the wall of the said mould to allow gas to pass therethrough, whereby the said sealing member initially releases gas and then seals the clearance between the said ram and the wall of the said mould against the passage of molten metal by deformation of the said sealing member under heat and pressure.

In another aspect the invention consists of apparatus for making metal castings with solidification under pressure by a process as defined above comprising a mould, a ram movable in the said mould with clearance therearound and adapted to apply pressure to molten metal in the said mould, and a sealing member made of a thin metal plate interposed between a pressure-applying surface of the said ram and molten metal in the mould, the said sealing member being made of thin metal plate and having a rim directed away from the ram to form a shallow dish-like shape and having a clearance between the peripheral edge of the rim and the wall of the mould to allow gas to pass therethrough.

The invention will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, wherein like reference characters indicate like parts throughout the Figures, in which:—

Figure 1 is a cross-sectional view of an apparatus showing an embodiment of the present invention:

Figures 2 and 3 are fragmentary sections similar to Figure 1 showing other embodiments; and

Figures 4 and 6 are sectional views of the Figure 3 apparatus with the ram in successively lowered positions during the casting operation.

Referring now more particularly to the drawings, Figure 1 illustrates an embodiment of the invention differing from conventional apparatus for casting with solidification under pressure in the addition of a thin metal plate 12 to the ram 3. Plate 12 is temporarily adhered by means of an adhesive, such as a resin, to the pressure applying end surface 4 of the ram 3. The remainder of the apparatus which is conventional includes a metal mould 1 having a cylindrical moulding space inside thereof, the upper portion of the cylinder being the pressure portion 2 and the bottom portion thereof being the casting shaping portion 6. The moulding space may have other and even irregularly shaped cross-sections. The mould 1 is fixed on the base 8 by means of bolts 9 and stands on a table 7.

In the conventional process, molten metal 11 is poured into said mould and pressed with the ram 3 capable of moving longitudinally within the pressure portion 2 by fluid, e.g., hydraulic, or any other pressure means (not shown) until the metal is solidified into a dense, fine grain, round bar. Nearly uniform clearance space 5 exists between the

ram 3 and the wall surface of the pressure portion 2 and the molten metal passes into this space to form flash, as explained above. The knock-out pin 10 is movable through an aperture in the base 8 to lift the casting out of the mould 1 upon completion of the process of casting.

The thin metal plate 12 is made of a material whose melting point is almost the same as, or higher than, that of the molten metal 11 to be cast, and is shaped as a disk whose diameter is nearly the same as, or slightly larger than, that of the pressure portion 2. The rim 121 of plate 12 is preferably turned inwardly in one direction. The thin metal plate 12 is placed against and affixed to the end surface 4 of the ram in such a manner that the inwardly turned rim 121 faces toward the surface of the molten metal 11 to be cast.

The disk 12 can be easily attached coaxially to the pressure applying end surface 4 of the ram by fitting a central projection 31 of the ram into a central hole 122 in the disk 12, as shown, for example, in Fig. 2. Alternatively, the disk 12 can be attached on the end surface 4 of the ram by inserting therebetween a thin plate 13 of compressed glass fibre, or ceramic fibre, of virtually the same disk-like form as the metal disk, as shown in Fig. 3. The disk 12, with or without disk 13, must be temporarily attached coaxially to the end surface 4 of the ram 4 by any suitable adherent means including the means mentioned above, such as adhesive, pins or bolts.

In use of the described inventive embodiments, when the ram 3 is pushed into the pressure portion 2 of the mould to press the molten metal, the gas at the surface of the molten metal 11 escapes through the clearance space 5 past the rim 121 of the metal plate 12. When the ram 3 is further lowered and the plate 12 touches the upper surface of the molten metal 11, the temperature of the plate 12 is quickly raised to the heat of the molten metal and the plate 12 is plastically deformed. During lowering of the ram 3, the rim 121 of the plate is pushed upwardly and spread outwardly by pressure of the molten metal 11 so that its outer edge fits closely against the cylindrical wall surface of the pressure portion 2 of the mould. This prevents the molten metal 11 from leaking into the clearance space 5, as the entrance of said clearance space is thus shut by the plate 12, and flash is not produced. Consequently, damage to the metal mould usually caused by flash in conventional casting is avoided and at the same time the pressure of the ram 3 is effectively applied to the molten metal because the edge of rim 121 of the plate 12, contacting against the cylindrical wall surface of the metal pressure portion of the mould, is softened and moves smoothly therealong with a minimum of friction.

Figs. 4 to 6 show successive positions of the ram in the mould and the resultant deformation of the thin plate 12 as the ram is lowered. Considering the casting of a metal in the iron family, preferably, plate 12 is of stainless steel of 0.3 mm. thickness and is attached to the end surface of the ram 3 by a thin glass fibre plate 13 inserted therebetween. The molten metal 12 to be cast is molten cast iron and the diameter of the cylindrical pressure portion 2 of the mould is 45 mm.

When the molten metal 11 is compressed under pressure of 2500 kg/cm^2, the stainless steel plate 12 contacts the molten metal, and then the outer edge of rim 121 is pushed up and out by the pressure of the molten metal (as shown by arrows in Fig. 4) closely to fit the cylindrical pressure portion 2. Upon further downward movement of the ram, the plate 12 is further deformed under greater pressure as is shown in Fig. 5, and finally takes the shape shown in Fig. 6.

The stainless steel plate 12 is softened by the high temperature, and its movement against the metal mould 1 is smoothly carried out, because the glass fibre disk 13 is melted and works as a lubricant to reduce the friction between stainless plate 12 and the metal mould 1. After the pressing operation is completed, the stainless steel plate 12 is adhered to the upper surface of the product, but it can be easily removed by simple mechanical processing, such as grinding, after the product is removed from the mould.

It will be readily apparent from the above description that the present invention improves the conventional process of casting with solidification under pressure by use of a sealing member in the form of a thin metal plate attached to the pressure applying surface of the pressure ram for contacting the surface of the molten metal. The added plate prevents the formation of flash in the clearance space between the ram and the mould, and as a result the friction between the flash and the metal mould is entirely eliminated. Thus, the life of the metal mould is greatly prolonged. At the same time the pressure of the ram is retained without undue loss in overcoming flash-friction and is effectively applied to the molten metal. The operation is very easily carried out as described, and can be effectively applied to all kinds of metals.

WHAT WE CLAIM IS:—

1. A process of casting metal with solidification under pressure which includes the steps of pouring molten metal into a mould, applying high pressure to said molten metal by means of a ram which is inserted in said mould with an initial clearance there-

around, and compressing said molten metal while it solidifies, comprising the step of inserting between a pressure-applying surface of the said ram and the said molten metal a sealing member made of a thin metal plate, the said sealing member having a clearance between its peripheral edge and the wall of the said mould so as to allow gas to pass therethrough, whereby the said sealing member initially releases gas and then seals the clearance between the said ram and the wall of the said mould against the passage of molten metal by deformation of the said sealing member under heat and pressure.

2. A process according to claim 1, comprising the step of inserting between the said pressure-applying surface of the ram and the said sealing member an additional sealing member made of a thin plate of a glass fibre or a ceramic fibre having a melting temperature below that of the said sealing member and below that of the molten metal, whereby the additional sealing member melts and lubricates the movement of the said sealing member along the wall of the mould while pressure is being applied to the molten metal.

3. Apparatus for making metal castings with solidification under pressure by a process according to claim 1 or 2 comprising a mould, a ram movable in the said mould with clearance therearound and adapted to apply pressure to molten metal in the said mould, and a sealing member made of a thin metal plate interposed between a pressure-applying surface of the said ram and molten metal in the mould, the said sealing member being made of thin metal plate and having a rim directed away from the ram to form a shallow dish-like shape and having a clearance between the peripheral edge of the rim and the wall of the mould to allow gas to pass therethrough.

4. Apparatus according to claim 3 wherein the said sealing member is made of stainless steel.

5. Apparatus according to claim 3 or 4 wherein the said sealing member is fastened to the said pressure-applying surface of the ram.

6. Apparatus according to claim 3, 4 or 5 comprising an additional sealing member made of a glass fibre or a ceramic fibre having a melting temperature below that of the said sealing member, the said additional sealing member being interposed between the ram and sealing member and melting during the pressure-applying operation to lubricate movement of the said sealing member and the ram along the mould wall surface.

7. Apparatus according to claim 6 wherein the said additional sealing member is curved at its periphery so as to form a dish-like rim directed away from the pressure-applying surface of the ram and toward molten metal in the mould.

8. Apparatus according to claim 7 wherein the said sealing member is fastened through the said additional sealing member to the pressure-applying surface of the said ram.

9. A process of casting metal with solidification under pressure according to claim 1 substantially as herein described with reference to the accompanying drawings.

10. Apparatus for making metal castings with solidification under pressure according to claim 3 substantially as herein described and shown in the accompanying drawings.

11. A metal casting made by a process or in apparatus as claimed in any preceding claim.

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1257963 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

FIG. 1.

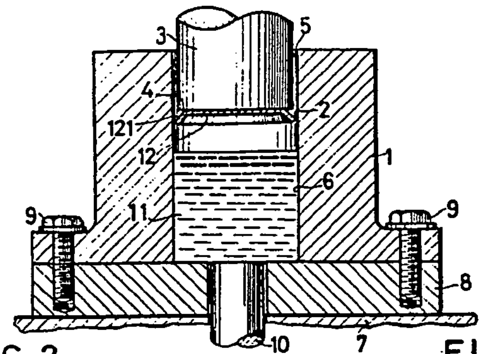

FIG. 2.

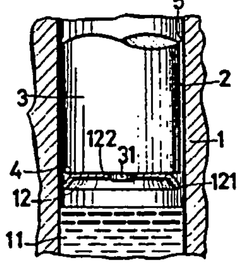

FIG. 3.

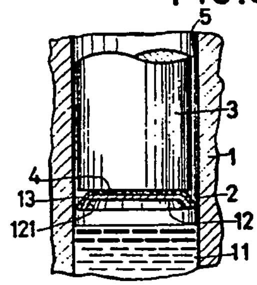

FIG. 4.

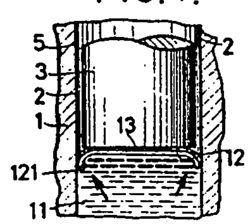

FIG. 5.

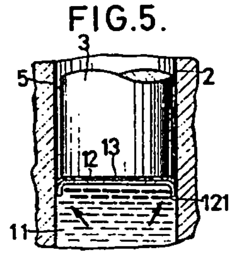

FIG. 6.